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L-P-391D
November 19, 1975
SUPERSEDING
Fed. Spec. L-P-391C
May 28, 1971

FEDERAL SPECIFICATION

PLASTIC SHEETS, RODS AND TUBING, RIGID CAST, METHACRYLATE (MULTIAPPLICATION)

This specification was approved by the Commissioner, Federal Supply Service, General Services Administration, for the use of all Federal agencies.

1. SCOPE AND CLASSIFICATION

1.1 Scope. This specification covers methacrylate sheets, rods and tubes produced by casting or machining cast blanks. This specification does not apply to heat-formed and molded or extruded shapes, or shapes made by assembling two or more pieces.

1.2 Classification (see 6.4)

1.2.1 Types and grades. The methacrylate sheets, rods, and tubes conforming to this specification shall be of the following items, types, and grades, as specified (see 6.2).

Item A - Plastic sheet.
Item B - Plastic rod.
Item C - Plastic tubing.
Item D - Plastic sheet having an abrasion resistant coating.

Type I - General purpose material having ultraviolet light absorbing properties.
Type II - Special use material not having an ultraviolet light absorber.
Type III - Type I sheet having an abrasion resistant coating on one or both sides.

The following grades apply to both types I and II material. Grades B and C sheet apply to type III sheet.

Grade A[1] - Special sheeting, thermally preshrunk sheet having a smooth glossy surface.

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Grade B[1] - Cell cast or continuous cast sheet, rods, and tubes having a matte or patterned finish.

Grade C[1] - Cell cast or continuous cast sheet, rods, and tubes having a smooth surface finish obtained either by casting or highly polishing the surface.

[1] All grades may be ordered trimmed to size or untrimmed.

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the issues in effect on date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

Federal Specifications:

PPP-B-585 - Boxes, Wood, Wirebound.
PPP-B-601 - Boxes, Wood, Cleated-Plywood.
PPP-B-621 - Boxes, Wood, Nailed and Lock-Corner.
PPP-B-636 - Box, Fiberboard.

Federal standards:

Fed. Std. No. 123 - Marking for Shipment (Civil Agencies).
Fed. Std. No. 00356 - Commercial Packaging of Supplies and Equipment.

(Activities outside the Federal Government may obtain copies of Federal Specifications, Standards, and Handbooks as outlined under General Information in the Index of Federal Specifications and Standards and at the prices indicated in the Index. The Index, which includes cumulative monthly supplements as issue, is for sale on a subscription basis by the Superintendent of Documents, U. S. Government Printing Office, Washington, D.C. 20402.

(Single copies of this specification and other Federal Specifications required by activities outside the Federal Government for bidding purposes are available without charge from Business Service Centers at the General Service Administration Regional Offices in Boston, New York, Washington, DC, Atlanta, Chicago, Kansas City, MO, Fort Worth, Denver, San Francisco, Los Angeles, and Seattle, WA.

(Federal Government activities may obtain copies of Federal Specifications, Standards, and Handbooks and the Index of Federal Specifications and Standards from established distribution points in their agencies.)

Military Specification:

MIL-P-116 - Preservation - Packaging, Methods of

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Military Standards:

MIL-STD-105 - Sampling Procedures and Tables for Inspection by Attributes.
MIL-STD-129 - Marking for Shipment and Storage.

(Copies of Military Specifications and Standards required by in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other publications. The following documents form a part of this specification to the extent specified herein. Unless a specific Issue is identified, the Issue in effect on date of invitation for bids or request for proposal shall apply.

American Society for Testing and Materials (ASTM) Standards:

D 542 - Index of Refraction of Transparent Organic Plastics.
D 618 - Conditioning Plastics and Electrical Insulating Materials for Testing.
D 637 - Surface irregularities of Flat Transparent Plastic Sheets.
D 638 - Tensile Properties of Plastics.
D 648 - Deflection Temperature of Plastics Under Flexural Load.
D 673 - Mar Resistance of Plastics.
D 756 - Resistance of Plastics to Accelerated Service Conditions.
D 792 - Specific Gravity and Density of Plastics by Displacement.
D 1003 - Haze and Luminous Transmittance of Transparent Plastics.
D 1044 - Resistance of Transparent Plastics to Surface Abrasion.
D 1308 - Effect of Household Chemicals on Clear and Pigmented Organic Finishes.
D 1499 - Operating Light and Water Exposure Apparatus (Carbon-Arc Type) for Exposure of Plastics.
D 1501 - Exposure of Plastics to Fluorescent Sunlamp.
D 3002 - Evaluation of Coatings for Plastics.

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.)

National Motor Freight Traffic Association, Inc., Agent:

National Motor Freight Classification.

(Application for copies should be addressed to the American Trucking Associations Inc., Tariff Order Section, 1616 P Street, N.W., Washington, D.C. 20036.)

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Uniform Classification Committee, Agent:

Uniform Freight Classification

(Application for copies should be addressed to the Uniform Classification Committee, Room 1106, 222 South Riverside Plaza, Chicago, Illinois 60606.)

3. REQUIREMENTS

3.1 Material. The cast sheets, rods, and tubes shall be composed of methacrylate plastics. Type III sheet shall consist of a cast methacrylate substrate having an abrasion resistant coating an one or both sides.

3.2 Property values. The sheets shall conform to the property values specified in table I and the rods and tubes shall conform to the property values specified in table II, when tested as specified in the applicable procedure of 4.3. For type III sheets, surface related tests shall be performed on the coated side or sides.

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TABLE I. Property values for cast sheets

Property	Type I	Type II	Type III	Remarks
Index of refraction, $n_D^{23°C}$. min.	1.49	1.48	NA[1/]	Clear and colorless material only.
max.	1.50	1.50	1.46	
Specific gravity[2/], min.	1.18	1.18	1.18	Unpigmented.
max.	1.20	1.20	1.20	
Haze, max., percent	3.0	3.0	2.0	Grades A and C colorless material only - not applicable to sheets over 1/2 inch in thickness.
Light transmittance, min., percent:				
0.060 to 0.187 in. thick	91	91	93	Colorless material, grades A and C only.
0.220 to 1.000 in. thick	89	89	91	
1.125 to 2.000 in. thick	87	87	89	
Spectral transmittance at any wavelength in the 290 to 330 nm. band, with 0.250 in. thick sheet, max., percent[3/]	5	NA	5	Colorless material, type I and type III, grade C only.
Displacement factor, max.[4/]				
0.060 to 0.500 in. thick	50	50	50	Grades A and C colorless and transparent colors in flat sheets only.
0.625 to 1.000 in. thick	80	80	80	
1.125 to 2.000 in. thick	125	125	125	
Shrinkage, max., percent:				
Grades B and C	2.8	2.8	2.8	Sheets only, must show no evidence of bubbling or blistering.
Grade A	1.0	1.0	NA	Sheets only, must show no evidence of bubbling or blistering.
Deflection temperature under load at 264 p.s.i., min., °C.				
0.060 to 0.500 in. thick[5/]	87	87	87	
Above 0.500 to 1.000	88	88	88	
Above 1.000 to 4.000	93	93	93	

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TABLE I. Property values for cast sheets (cont'd)

Property	Type I	Type II	Type III	Remarks
Tensile strength, min., p.s.i.	9000	9000	9000	
Elongation at rupture, min., percent	2	2	2	
Abrasion resistance, max., percent haze	NA	NA	4.0	Before and after simulated weathering conditioning. Before and after accelerated service conditioning.
Mar resistance, max., percent haze	NA	NA	4.0	Before and after simulated weathering conditioning. Before and after accelerated service conditioning.
Coating adhesion, min., percent retention	NA	NA	88	Before and after simulated weathering conditioning. Before and after accelerated service conditioning.
Chemical resistance, visual examination for surface alteration	NA	NA	No change	Type III only.

1/ NA indicates not applicable.
2/ For pigmented material, specific gravity shall be as specified by the procuring agency.
3/ When testing other thickness, the value found shall be adjusted to 0.250 in. thickness. Thick sheet shall be machined to 0.250 in. thickness and polished.
4/ Applies to the area greater than 3 in. from the edge of the sheet.
5/ For thickness less than 0.060 inches, deflection temperature shall be as specified by the procuring agency.

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TABLE II. Property values for cast rods and tubes

Property	Type I	Type II
Index of refraction, n_D 23 deg. C. min.	1.48	1.40
max.	1.50	1.50
Specific gravity[1], min.	1.18	1.18
max.	1.20	1.20
Spectral transmittance at any wavelength, in the 290 to 330 nm. band, 0.250 in. thickness max. percent[2]	5	NA[3]
Deflection temperature under load at 264 p.s.i., min. deg. C.		
0.060 to 0.500 in. thick	87	87
Above 0.500 to 1.000	90	90
Above 1.000	93	93
Tensile strength, min., p.s.i.	8000	8000
Elongation at rupture, min., percent	2	2

[1] For pigmented material, specific gravity shall be as specified by the procuring agency.

[2] When testing other thicknesses, the value found shall be adjusted to 0.250 in. thickness. Thick rods, tubes, and shape* shall be machined to 0.250 in. thickness and polished for testing.

[3] NA indicates not applicable.

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3.3 Thermal stability (applicable to grades A, D, and C sheet). Grades A, B, and C sheet shall show no evidence of bubbling or blistering when subjected to the thermal stability test.

3.4 Simulated weathering resistance.

3.4.1 Types I and II sheet. When specified by the procuring agency (see 6.2), types I and II sheet shall be subjected to simulated weathering (see 4.3.13.1) and shall show no evidence of cracking, crazing, surface instability, discoloration, or other changes which prevent light transmittance and haze properties from meeting the requirements specified in table I.

3.4.2 Type III sheet. Type III sheet shall be subjected to simulated weathering (see 4.3.13.2) and shall show no evidence of surface deterioration which prevents abrasion and mar resistance, coating adhesion, and light transmittance properties from meeting the applicable requirements specified in table I.

3.5 Accelerated service conditions resistance (applicable only to type III sheet). Type III sheet shall be subjected to accelerated service conditioning (see 4.3.14) and shall show no evidence of change in abrasion and mar resistance, and coating adhesion properties (see table I).

3.6 Color. Unless otherwise specified, sheets, rods, and tubes shall be colorless. When color is specified, certain optical properties, including refractive index, haze, and luminous transmittance, are not applicable. The method of determination and the uniformity of the color shall be specified by the procuring agency in consultation with the supplier (see 6.2).

3.6.1 End color of rods and tubes. When required, end color of rods and tubes shall not exceed the limit defined by the color standard specified by the procuring agency. The method of examination shall be as specified by the procuring agency (see 6.2).

3.7 Dimensions and tolerances. All measurements shall be made either at 23 deg. +/- 2 deg. C (73.4 deg. +/- 3.6 deg. F), or corrected to 23 deg. C (73.4 deg. F). When correction to 23 deg. C (73.4 deg. F is required, pertinent information, including measurement temperature, shall be reported to the procuring agency.

3.7.1 Sheets. The nominal length, width and thickness shall be as specified by the procuring agency (see 6.2). For trimmed sheets, types I and II, tolerance on length and width shall be +/- 0.125 inch. For untrimmed sheets, types I and II, up to and including 1/2 inch thick, length and width shall be not less than 2.5 percent larger than nominal. For untrimmed sheets, types I and II, greater than 1/2 inch through 4 inches thick, length and width shall be not less than 1 percent larger than nominal. Tolerances for thickness of cell cast sheets shall be as specified in tables III and IV.

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Tolerances and thickness of continuous cast sheet shall be as specified in table V. The standard widths for continuous cast sheet shall be 36 inches through 96 inches and standard length shall be as specified in table V. Type in sheet, cut to trimmed sizes, shall have the same tolerances as type I sheet. Untrimmed type III sheet may have one or more edges trimmed, but the dimensions. supplied shall be equal to or larger than nominal.

TABLE III. Nominal thickness and tolerances for grade A (preshrunk) call cast sheets

Nominal thickness inch	Permissible thickness variation, inch		
	Size 1 [1]	Size 2 [2]	Size 3 [3]
0.060	+/-0.017	+/-0.025	NA [4]
0.080	+/-0.017	+/-0.025	NA
0.100	+/-0.017	+/-0.025	NA
0.125	+/-0.020	+/-0.025	+/-0.035
0.187	+/-0.025	+/-0.030	+/-0.035
0.250	+/-0.030	+/-0.035	+/-0.040
0.312	+/-0.035	+/-0.040	+/-0.045
0.375	+/-0.040	+/-0.045	+/-0.050
0.500	+/-0.045	+/-10.05	+/-0.050
0.625	+/-0.055	+/-0.055	+/-0.055
0.750	+/-0.055	+/-0.055	+/-0.060
0.875	+/-0.055	+/-0.055	+/-0.070
1.000	+/-0.055	+/-0.055	+/-0.075
1.250	+/-0.070	+/-0.070	+/-0.100
1.500	+/-0.080	+/-0.080	+/-0.120
1.750	+/-0.095	+/-0.095	+/-0.140
1.875	+/-0.105	+/-0.105	+/-0.155
2.000	+/-0.105	+/-0.105	+/-0.155

[1] Size 1 - Nominal sheet sizes 36 by 60 inches and smaller, and 40 by 50 inches and smaller.

[2] Size 2 - Nominal sheet sizes larger than size 1 up to and including 46 by 84 inches, 53 by 80 inches, and 60 by 72 inches.

[3] Size 3 - Nominal sheet sizes larger than size 2 up to and including 67 by 102 inches, and 72 by 96 inches.

[4] NA indicates not applicable.

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TABLE IV. Nominal thickness and tolerance for grades B and C cell cast sheets

Nominal thickness, inch [1]	Permissible variation, inch		
	Size 1 [2]	Size 2 [3]	Size 3 [3]
0.030	+0.007 -0.009	NA	NA [6]
0.040	+0.006 -0.010	NA	NA
0.050	+0.006 [5] -0.010	NA	NA
0.060	+0.015 -0.019	+0.024 -0.027	NA
0.080	+0.014 -0.020	+0.022 -0.028	NA
0.100	+0.013 -0.021	+0.021 -0.029	NA
0.125	+0.015 -0.025	+0.020 -0.030	+0.030 -0.040
0.150	+0.016 -0.030	+0.022 -0.036	+0.029 -0.050
0.187	+0.017 -0.033	+0.022 -0.038	+0.027 -0.043
0.220	+0.020 -0.040	+0.025 -0.045	-0.029 -0.050
0.250	+0.020 -0.040	+0.025 -0.045	+0.030 -0.050
0.312	+0.022 -0.048	+0.027 -0.053	+0.032 -0.058
0.375	+0.025 -0.055	+0.030 -0.060	+0.035 -0.065
0.500	+0.025 -0.065	+0.030 -0.070	+0.035 -0.075

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TABLE IV. Nominal thickness and tolerance for grades B and C cell cast sheets (cont'd)

Nominal thickness, inch [1]	Permissible variation, inch		
	Size 1 [2]	Size 2 [3]	Size 3 [3]
0.625	+0.033 -0.077	+0.033 -0.077	+0.036 -0.082
0.750	+0.030 -0.080	+0.030 -0.080	+0.040 -0.090
0.875	+0.026 -0.084	+0.026 -0.084	+0.046 -0.104
1.000	+0.023 -0.087	+0.023 -0.087	+0.048 -0.112
1.250	+0.052 -0.094	+0.052 -0.094	+0.052 -0.094
1.500	+0.039 -0.121	+0.039 -0.121	+0.077 -0.159
1.750	+0.049 -0.137	+0.049 -0.137	+0.092 -0.180
2.000	+0.058 -0.152	+0.058 -0.152	+0.108 -0.202
2.250	+0.070 -0.166	+0.070 -0.166	NA
2.500	+0.079 -0.181	+0.079 -0.181	NA
2.750	+0.092 -0.194	+0.092 -0.194	NA
3.000	+0.102 -0.208	+0.102 -0.208	NA
3,250	+0.114 -0.222	+0.114 -0.222	NA

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TABLE IV. Nominal thickness and tolerance for grades B and C cell cast sheets (cont'd)

Nominal thickness, inch [1]	Permissible variation, inch		
	Size 1 [2]	Size 2 [3]	Size 3 [3]
3.500	+0.121 -0.239	+0.121 -0.239	NA [6]
3.750	+0.134 -0.252	+0.134 -0.252	NA
4.000	+0.142 -0.268	+0.142 -0.268	NA

[1] Thickness of unshrunk sheet will increase approximately 4 percent when it is heated at thermoforming temperatures.

[2] Size 1 - Nominal sheet sizes 36 by 60 inches and smaller, 40 by 50 inches and smaller.

[3] Size 2 - Nominal sheet sizes larger than size 1 up to and including 48 by 84 inches, 53 by 80 inches, and 60 by 72 inches.

[4] Size 3 - Nominal sheet sizes larger than size 2 up to and including 67 by 102 inches, and 72 by 96 inches. Sheet sizes 48 by 120, and 84 by 132 inches are available in nominal thicknesses of 0.125, 0.187, and 0.250 inch, and in grade A only.

[5] For colorless sheet only, tolerances shall be +0.014, -0.009 for 0.030 inch thickness, +0.013, -0.017 for 0.040 inch thickness, and +0.013, -0.017 for 0.050 inch thickness.

[6] NA indicates not applicable.

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TABLE V. Nominal thickness, length, and tolerances for Grades B and C continuous cast sheeting [1]

Nominal thickness, inch	Permissible variation in thickness, inch as supplied in reel form or flat sheet	An supplied in reel form	
		Standard nominal length in feet [2]	Permissible variation in length, feet
0.080	+/-0.010	[2]	-0, +1
0.100	+/-0.010	[2]	-0, +1
0.110	+/-0.011	[2]	-0, +1
0.125	+/-0.012	[2]	-0, +1
0.135	+/-0.013	[2]	-0, +1
0.150	+/-0.015	[2]	-0, +1
0.170	+/-0.017	[2]	-0, +1
0.187	+/-0.019	[2]	-0, +1
0.220	+/-0.022	[2]	-0, +1
0.250	+/-0.025	[2]	-0, +1

[1] If defective portions are included in a continuous reel, they shall not exceed 10% of the total length in feet supplied. The length of any such defective portions are to be credited (deducted from the gross footage supplied) at no cost to the purchaser.

[2] Nominal lengths of reels shall be as agreed upon between supplier and procuring agency. Standard lengths vary from 250 to 750 feet as thickness decreases. Nominal widths are 8 feet.

3.7.2 Rods. The nominal length and diameter shall be as specified by the procuring agency (see 6.2). The tolerance on length shall be +/- 0.0625 inch with Diameters no greater than 3.00 inches, and 0.125 inch for rods with diameters above 3.00 inches. Tolerances for diameter shall be as specified in table VI.

TABLE VI. Nominal diameter and tolerances of cast rods

Nominal diameter, inch	Diameter tolerances, inch
0.25 to 0.50	+/-0.005
0.625 to 1.00	+/-0.010
1.125 to 2.00	+/-0.015
2.25 to 3.00	+/-0.030
3.25 to 5.5	+/-0.040
6.0 to 8.5	+/-0.050
9 to 11	+/-0.060

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3.7.3 Tubes. The nominal length, outside diameter, and wall thickness shall be as specified by the procuring agency(see 6.2). The tolerance on outside diameter and wall thickness shall be as specified in tables VII and VIII. The tolerance for length shall be +/- 0.0625 inch.

TABLE VII. Nominal outside diameter and tolerance of cast tubes

Nominal outside diameter, inch	Outside diameter tolerance, inch		Difference between maximum and minimum outside diameter (one tube) not to exceed, inch
	Plus	Minus	
1.500 to 3.000	0.010	0.020	0.025
3.125 to 3.875	0.015	0.030	0.040
4.000 to 6.094	0.015	0.045	0.060
7.000 to 12.000	0.015	0.065	0.080

TABLE VIII. Nominal wall thickness and tolerances of cast tubes

Nominal wall thickness, inch	Permissible wall thickness tolerance, inch
0.125	+/-0.015
0.150	+/-0.019
0.187	+/-0.019
0.250	+/-0.025
0.375	+/-0.035
0.500	+/-0.045
0.750	+/-0.060

3.8 Workmanship. The sheets, rods, and tubes shall be free from warpage, cracks, scratches, blisters, voids, foreign matter and other defects that may affect appearance or which may affect serviceability. Bubbles in rods and tubes shall not exceed 0.156 inch in any dimension, and no more than three such bubbles are acceptable in any standard length not less than 48 inches. Bubbles are not permitted in rods and tubes less than 48 inches in length.

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3.8.1 Flatness of sheets (applicable only to cell cast sheets). Types I and II sheet shall be free from edge kink warpage and from edge "S" warp. Type III sheet less than or equal to 0.125 inch thick may have "S" warp with a maximum deviation of 1.0 inch from a flat surface. Type III sheet greater than 0.125 inch thick shall be free from edge kink warpage and from "S" warp. Overall bow warp is permitted for all types of sheet if it can be displaced by light finger pressure to conform to a flat surface.

3.8.2 Corner letgoes for sheets (applicable to either trimmed or untrimmed sheets). Masked sheets in thicknesses equal to or less than 2.000 inches shall be free of corner letgoes. Unmasked sheets in thicknesses no greater than 0.250 inches may have letgoes within any or all of the corner areas which are defined as isosceles triangles with 3-inch sides. Corner letgoes in unmasked sheets that are thicker than 0.250 inches up to and including 2.000 inches are permitted within any or all of the corner areas which are defined as isosceles triangles with 6-inch sides. For unmasked sheets out-of-tolerance corner letgoes' within an isosceles triangle that has no more than twice the allowable length for sides, shall be accepted if removed. For masked and unmasked sheets in thicknesses greater than 2.000 inches, letgoes may exist provided they do not extend more than 1/64 inch below the surface. For continuous cast sheet only, edge letgoes less than 1/64 inch in depth may exist within one inch of the sheet edges provided physical integrity is not impaired.

3.8.3 Chips and dirt in sheets.

3.8.3.1 Chips for sheets in thickness equal to or less than 2.000 inches. For type I and type II sheet, maximum permissible size shall be 0.125 inch. For type III sheet, maximum permissible size shall be 0.187 inch. Chips that are approximately the maximum permissible size for each type of sheets, shall not have a frequency greater than one chip per 4 square feet of sheet area. Chips less than the maximum permissible size for each type of sheet shall not form a concentrated pattern that may affect serviceability. Chips out-of-tolerance in size may be knifed off and considered acceptable if the remaining blemish could be removed by polishing, except for type III sheets which cannot be easily polished.

3.8.3.2 Chips for sheets in thicknesses greater than 2.000 inches. Chips may exist providing they do not extend more than 1/64 inch above the surface.

3.8.3.3 Dirt and contaminants. For type I and type II sheet, maximum permissible dimension shall be 0.125 inch. For type III sheet, maximum allowable dimension shall be 0.187 inch. Dirt and contaminants less than 1/32 inch shall be disregarded. The maximum permissible frequency for dimensions ranging from 1/32 inch to the maximum permissible for each type of sheet shall be one per 4 square feet of sheet area oar thickness up to and including 0.500 inch, and 1 per square foot for thickness exceeding 0.125 inch.

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3.8.4 Other defects in sheets, rods, and tubes. Minor type defects such as mold or handling scratches which can be removed by polishing shall be permitted for type I and type II sheet provided these are not objectionable individually or in grouped patterns. For type III sheet, maximum permissible length for mold scratches shall be 1 inch; maximum permissible length for medium or heavy handling scratches or abrasions shall be 2 inches; maximum permissible length of light handling scratches or abrasions shall be 6 inches; scratches or abrasions lose than 0.250 inch and back-to-back mold scratches shall be disregarded unless they form a concentrated pattern that may affect serviceability. For type III sheet, the maximum permissible frequency for allowable scratches and abrasions as defined above shall be one per 4 square feet of sheet area. Excluding side letgoes for types I, II, and III sheets in thicknesses greater than 2.000 inches and for unmasked sheets that are thicker than 0.250 inches up to and including 2.000 inches, defects within one inch of the untrimmed edge of the sheet, which do not significantly reduce mechanical strength of the sheet, shall be permitted. Side letgoes for sheets thicker than 2.000 inches may exist providing they do not extend more than 1/64 inch below the surface. Side letgoes for unmasked sheets thicker than 0.250 inches and up to and including 2.000 inches shall be allowed within a 2 inch band from the untrimmed edge of the sheet. Rods and tubes shall be free of striae and other blemishes that may affect serviceability.

3.8.4.1 Optical clarity of rods (applicable to grade C only). Grade C cast rods in 20 inch lengths, after polishing the ends, shall have optical clarity that will enable clean print of the size 7 lines per column inch and 16 characters to the linear inch to be read when viewed through the length of the rod under good illumination. The optical clarity of rods 3 inches and less in diameter shall not be impaired by heating for the time period* and temperatures specified in table IX, followed by cooling to 23 deg. +/- 2 deg. C (73.4 deg. +/- 3.6 deg. F) before testing.

TABLE IX. Heating conditions for determining stability of optical clarity of rods [1]

Rod diameter, inches	Temperature	Time, minutes
0.250 to 0.500	150 deg. C (302 deg. F)	30
0.625 to 1.5	145 deg. C (293 deg. F)	50
1.625 to 3.00	145 deg. C (293 deg. F)	75

[1] Rods larger than 3.0 inches in diameter and machined from large castings, will not pass the optical clarity test after the heating cycle.

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3.8.4.2 Turbidity of rods and tubes (applicable to grade C only). When required, turbidity of grade C rods and tubes shall not exceed the limit defined by a turbidity standard specified by the procuring agency. The method of examination shall be as specified by the procuring agency (see 6.2).

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own facilities or any commercial laboratory acceptable to the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure that supplies and services conform to prescribed requirements.

4.2 Sampling for inspection and acceptance. Sampling for inspection and acceptance shall be performed in accordance with the provisions set forth in MIL-STD-105, except where otherwise indicated. For purposes of sampling, an inspection lot for examination and tests shall consist of all material of the same type, grade, and nominal thickness submitted for delivery at one time.

4.2.1. Inspection of materials and components. In accordance with 4.1, the supplier is responsible for insuring that materials and components used, were manufactured, tested, and inspected in accordance with the requirements of this specification, and to the extent specified. of all referenced subsidiary specifications and standards. In the event of conflict, this specification shall govern. A supplier’s certificate of compliance with 3.1 shall be furnished.

4.2.2 Inspection of material.

4.2.2.1 Inspection of sheets, rods and tubes. Examination of sheets, rods, and tubes shall be made in accordance with the classification of defects, inspection levels and acceptable quality levels (AQLs) set forth below. The lot size, for purpose of determining the ample size in accordance with MIL-STD-105, shall be expressed in units of packages of plastic sheets, rods, or tubes for examination in 4.2.2.1, and 4.2.2.2, and in units of shipping containers for examination in 4.2.2.3.

4.2.2.1.1 Examination of sheets. rods, and tubes for defects in Appearance and workmanship. The sample unit for the examination specified in table X shall be one sheet, rod, or tube.

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TABLE X. Examination of sheets, rods, and tubes for defects in appearance and workmanship

Examine	Defects
Sheets, rods and tubes	Not free from warpage, cracks, scratches, blisters, voids, and foreign matter (see 3.8).
Rods and tubes	Bubbles not in accordance with 3.8.
Sheets	Not free from edge kink warpage and edge "S" warp (see 3.8.1). Not in accordance with 3.8.1 for type III sheet equal to or less than 0.125 inch thick.
Sheets	Letgoes exceeding dimensions specified (see 3.8.2).
Sheets	Chips or dirt not in accordance with requirements (see 3.8.3.1, 3.8.3.2, and 3.8.3.3). Other defects not in accordance with requirements (see 3.8.4).

4.2.2.1.2 Examination of sheets, rods, and tubes for defects in dimensions. The sample unit for the examination specified in table X shall be one sheet, rod, or tube.

TABLE XI. Examination of sheets, rods, and tubes for dimensional defects

Examine	Defects
Sheets	Nominal length, width, or thickness not as specified. Length or width tolerance not an specified in 3.7.1. Thickness tolerance not as specified in tables III, IV, and V.
Rods	Nominal length and diameter not as specified. Tolerance for length not as specified in 3.7.2. Tolerances for diameter not as specified in table VI.
Tubes	Nominal length, outside diameter, and wall thickness not as specified. Tolerance for outside diameter not as specified in table VII. Tolerance for wall thickness not as specified in table VIII. Tolerance for length not as specified in 3.7.3.

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4.2.2.1.3 Examination of preparation for delivery. An examination in accordance with table XII, shall be made to determine that packaging, packing, and marking comply with specified contract requirements. The sample unit for this examination shall be one shipping container fully packed, selected just prior to the closing operation. Shipping containers fully prepared for delivery shall be examined for closure defects.

TABLE XII. Examination for defects in preparation for delivery

Examine	Defect
Packaging	Not level specified. Not individually packaged, multiple packaged, or intermediate packaged, as specified. Packaging material not as specified: closure not accomplished by specified or required methods or materials; component missing. Weight of intermediate package exceeds specified requirements.
Packing	Not level specified. Containers not as specified, closures not accomplished by specified or required method of materials. Any nonconforming component, component missing, damaged or otherwise defective, affecting serviceability.
Count	Less than specified or indicated quantity.
Weight	Gross weight exceeds specified requirements.
Markings	Interior or exterior markings, as applicable, omitted, illegible, incorrect, incomplete, of improper size, location, sequence or method of application, or not in accordance with contract requirements.

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4.2.2.1.4 Inspection levels and AQLs for examinations. The inspection levels for determining the sample size and the AQL, expressed an defects per 100 units shall be as follows:

Examination paragraph	Inspection level	AQL
4.2.2.1.1	I	2.5
4.2.2.1.2	S-2	4.0
4.2.2.1.3	S-2	2.5

4.2.3 Testings. The sheets shall be tested for the applicable characteristics listed in table I, and the rods and tubes for the applicable characteristics listed in table II, in accordance with the test method specified herein f or each lot submitted for inspection. The lot size, for the purpose of determining sample size for testing shall be expressed in units of packages of sheets, rods, or tubes, as applicable. The sample unit shall consist approximately of only sufficient material to prepare all required specimens. The inspection level shall be S-1 with an acceptance number of 0. When the test method requires testing more than one specimen, the results for each test shall be the averaged results of the specimens.

4.2.3.1 Classification of tests. All tests shall be classified as follows:

a. Lot acceptance tests (see 4.2.3.2).
b. Periodic lot check tests (see 4.2.3.3).

4.2.3.2 Lot acceptance tests. Lot acceptance tests shall be made on each lot of sheets, rods, or tubes, as applicable, and, in conjunction with the above examination, shall be the basis for acceptance or rejection of the lot, except when periodic lot check tests are required. For type I and II sheet, lot acceptance tests shall consist of tests for specific gravity, spectral transmittance (for type I only), shrinkage, and deflection temperature under load (see table I). For type III sheet lot acceptance tests shall consist of tests for specific gravity, spectral transmittance, deflection temperature under load, abrasion resistance, mar resistance and coating adhesion (see table I). For rods and tubes, lot acceptance tests shall consist of tests for specific gravity, spectral transmittance (for type I only), and deflection temperature under load (see table II).

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4.2.3.3 Periodic lot check tests. Periodic lot check tests shall be made on the first lot of material furnished under this specification, and on any subsequent lot specified by the procuring agency (see 6-2). For grades B and C sheet, periodic lot check tests shall consist of all tests specified in table I and the thermal stability test (see 3.3). For grade A sheet, periodic lot check tests shall consist of all tests specified in table I. For type III sheet, periodic lot check tests shall consist of all tests specified for grade C and the simulated weathering and accelerated service conditions tests (see 4.3.13.2 and 4.3.14). For rods and tubes, periodic lot check tests shall consist of all tests specified in table II. When periodic lot check tests are made, they shall be included in the basis for acceptance or rejection of the lot.

4.3 Test methods.

4.3.1 Test specimen preparation. Unless otherwise specified, the dimensions of specimens shall conform to that specified in the applicable test procedure.

4.3.1.1 Sheets. Test specimens shall be cut from sheet. When 0.250 inch thick sheet is not available for spectral transmittance determination, lower thicknesses may be used with adjustment of the values to that for 0.250 inch thick specimens. The method of adjustment shall be as specified by the procuring agency (see 6.2). Sheets with thickness greater than 0.250 inch shall be machined to 0.250 inch thickness and polished before measuring spectral transmittance.

4.3.1.2 Rods and tubes. Test specimens shall be cut from the rods or tubes, as applicable, if test specimens cannot be cut from rods or tubes, specimens shall be prepared from the same material under conditions specified by the manufacturer.

4.3.2 Test specimen conditioning. Unless otherwise specified, test specimens shall be conditioned in accordance with procedure A of ASTM D 618 and tested at 23 deg. 2 deg. C (73.4 deg. +/- 3.6 deg. F) and 50 +/- 5 percent relative humidity.

4.3.3 Index of refraction. One specimen shall be tested in accordance with ASTM D 542.

4.3.4 Specific gravity. One specimen shall be tested in accordance with method A of ASTM D 792.

4.3.5 Haze (applicable only to grade C sheet). One specimen shall be tested in accordance with ASTM D 1003, except that test specimens shall not exceed 0.500 inches in thickness.

4.3.6 Light transmittance (applicable only to grade C sheet). One specimen shall be tested in accordance with ASTM D 1003, at the same time it is tested in accordance with 4.3.5.

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4.3.7 Spectral transmittance in the ultraviolet region (applicable only to type I and type III grade C sheet, and type I rods and tubes). One specimen shall be tested for spectral transmittance in 290 to 330 nonometers (nm.) wavelength band. The spectral transmittance shall be determined by means of a monochromator having a band width of 10 on. or less and a photometer having a reproducibility of +/- 1 percent of full scale.

4.3.8 Displacement factor (applicable only to grade C sheet). One test specimen 18.0 +/- 0.1 by 18.0 +/- 0.1 inch shall be tested in accordance with ASTM D 637.

4.3.9 Shrinkage (applicable to sheet only). Two specimens, each 12.0 ± 0.1 by 12.0 +/- 0.1 inch, shall be tested. On each specimen, two fine lines shall be marked at right angles to each other entirely across the specimen from the midpoints of opposite sides. Fine gage marks shall be placed across each of these lines and 2.0 +/- 0.1 inches from the edge of the specimen. The distance between each pair of gage marks shall be measured to the nearest 0.01 inch. Each specimen shall be suspended from one end in a circulating air oven at 180 deg. +/- 10 deg. C (320 deg. +/- 18 deg. F), for the length of time specified in table XIII. After removal from the oven, the specimens shall be allowed to cool to 23 deg. +/- 1 deg. C (73.4 deg. +/- 1.8 deg. F), while in the suspended position. The distance between each pair of gage marks shall be remeasured and the shrinkage calculated as the percentage change in distance between gage marks based on the original distance.

TABLE XIII. Heating time for shrinkage test

Nominal sheet thickness, [1] inches	Minimum heating time, minutes
0.250 and less	16
0.375	25
0.500	33
0.750	55
1.000	79
1.500	136
2.000	203
2.250 and above	240

[1] For thickness falling between that specified, use the heating time for the next higher thickness.

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4.3.10 Deflection temperature under load. Three specimens shall be tested in accordance with ASTM D 648. Any square, rectangular, or cylindrical test specimen may be used, but the test load must be calculated on the basis of a center-loaded beam in which the outer fiber stress produced is 264 p.s.i. Pieces of thin sheet shall be staked and bound together to 0.500 t 0.050 inch in width to form a specimen 0.500 +/- 0.050 by 0.500 +/- 0.050 inch. Specimens shall be loaded parallel to the faces containing the original surfaces of material. Specimens 0.500 +/- 0.050 by 0.500 +/- 0.050 inch, machined from face of thick material, shall be loaded parallel to the face containing the original surface.

4.3.11 Tensile strength and elongation. Three specimens shall be tested in accordance with ASTM D 638, using testing speed B. Dimensions of each specimen shall conform to type I of figure 1 of ASTM D 638 and shall be of the thickness an received, except when thickness exceeds 1.00 inch. When thickness exceeds 1.00 inch, the specimen shall be machined down to a convenient thickness not exceeding 1.00 inch.

4.3.12 Thermal stability. Two sheets, each 12 by 12 inches, shall be tested. Each sheet shall be hung in a circulating air oven at 180 deg. +/- 5 deg. C (356 +/- 9 deg. F). Time of heating shall be 1/2 hour for 3/8 inch thickness and under, 1 hour for above 3/8 inch to 1 inch inclusive, and 2 hours for over 1 inch thickness. After removal from the oven, the sheeting shall be permitted to cool to 23 deg. +/- 2 deg. C (73.4 deg. +/- 3.6 deg. F) while hanging vertically. The sheeting shall be examined visually for the presence of bubbles and blisters.

4.3.13 Simulated weathering resistance.

4.3.13.1 Types I and II sheet (required only when specified by the procuring agency (see 3.4 and 6.2). Two specimens shall be tested in accordance with procedure C of ASTM D 1501. Specimens shall be of convenient dimensions and not exceed 0.236 inches in thickness.

4.3.13.2 Type III sheet. Two specimens shall be tested in accordance with ASTM D 1499 for 1000 +/- 10 hours. Specimens shall be of convenient dimensions, but not smaller than 2.75 by 4.0 inches, and shall be subjected to the water spray cycle. For one side coated sheet, the coated side shall be exposed.

4.3.14 Accelerated service conditions resistance (applicable only to SW III sheet). Six specimens shall be tested in accordance with procedure A of ASTM D 756. Tests 4.3.15, 4.3.16, and 4.3.17 shall be run after 8.4 and 8.10 of procedure A of ASTM D 756.

4.3.15 Abrasion resistance (Applicable to type III sheet only). One specimen shall be tested in accordance with ASTM D 1044, using a 500 gram load on each wheel for 100 cycles.

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4.3.16 Mar resistance (applicable to type III sheet only). One specimen shall be tested in accordance with ASTM D 673 using 1000 grams of No. 80 silicon carbide (carborundum or equivalent) as the abrasive.

4.3.17 Coating adhesion (applicable to type III sheet only). One specimen shall be tested in accordance with section 8.1 of ASTM D 3002, except as follows: The surface shall be cleaned using isopropyl alcohol with a soft cloth and then air dried. Four parallel cuts shall be made 1/8 inch apart and a similar set of cuts 90 degrees to the first. The debris shall be removed with light hand rubbing using 0000 grade steel wool being careful not to contaminate the test area with grease or fingerprints. A strip of 1.0 inch wide cellulose tape (3M Company #600 or equivalent) shall be applied pressing the tape down firmly without wrinkles or bubbles. The tape shall be removed immediately by quickly pulling it at a 90 degree angle. The tape pull shall be repeated two times in the same grid area being careful not to contaminate the grid by touching it. The area from which the coating has been removed shall be estimated, expressing it as a percentage of the total area within the grid.

4.3.18 Chemical resistance (applicable to type III sheet only). One specimen shall be tested in accordance with section 5.2 of ASTM D 1308 except that a 1/2 by 1/2 inch square of filter paper shall be saturated on the surface to be tested with 1 ml of reagent and covered with a watch glass. After one hour, the glass and filter paper shall be removed and the surface flushed with methanol to remove the reagent. The area shall be wiped dry and examined for effects listed in section 1 of ASTM D 1308. Test reagents shall be:

3% trisodium phosphate
40% sulfuric acid
toluene

5. PREPARATION FOR DELIVERY

5.1 Preservation and packaging shall be level A or C, as specified (see 6.2).

5.1.1 Level A. maximum Military protection. Unless otherwise specified in the contract or order (see 6.2), sheet, rods, and tubes shall be packaged in quantities specified by the procuring agency in accordance with method III of MIL-P-116. Shapes of only one set of nominal dimensions shall be placed in one package. Individual sheets shall be masked or unmasked at the option of the procuring agency.

5.1.2 Commercial. Sheets, rods, and tubes shall be packaged to provide a sufficient level of protection to prevent deterioration during shipment and to ensure safe delivery at destination.

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5.1.3 Disposability (see 6.5).

5.2 Packing. Packing shall be level A, B, or C, as specified (see 6.2)

5.2.1 Level A. maximum Military protection. Sheet, rods and tubes packaged as specified in 5.1.1 shall be separated by form, diameter and wall thickness, and shall be packed in containers conforming to any of the following specifications, at the option of the supplier:

Specification	Type or class
PPP-B-585	Class 3
PPP-B-601	Overseas type
PPP-B-621	Class 2

Boxes shall be closed, strapped, or banded in accordance with the applicable box specification or appendix. The gross weight of the shipping container shall be as specified in the applicable container specification.

5.2.2 Level B. minimum Military protection. Packages of sheet, rods, or tubes shall be packed in domestic class or type shipping containers conforming to PPP-B-585, PPP-B-601, PPP-B-621, or PPP-B-636. All containers be closed in accordance with the applicable container specification or appendix. The gross weight of the shipping container shall be as specified in the applicable specification.

5.2.3 Commercial. The sheet, including rolls of sheeting, rod or tubes,, packaged as specified in 5.1, shall be packed in a manner to erasure carrier acceptance and safe delivery at destination at the lowest transportation rate for such supplies. Containers shall be in accordance with Uniform Freight Classification Rules or National Motor Freight Classification Rules, as applicable.

5.2.4 Disposability (see 6.5).

5.3 Marking.

5.3.1 Civil agencies. Unit packages and shipping containers shall be marked in accordance with Fed. Std. No. 123.

5.3.2 Military agencies. In addition to any special marking required by the contract or purchase order, unit packages and shipping containers shall be marked in accordance with MIL-STD-129. When individual sheets are masked, the applicable FSN of the sheet shall be marked on the masking material in at least one place on each sheet.

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5.3.3 Commercial. Unit packages and shipping containers shall be marked in accordance with Fed. Std. No. 00356.

6. NOTES

6.1 Intended use. The sheet, rods and tubes covered by this specification are intended for use in applications where transparency, color range, weather resistance and other characteristics of cast acrylic shapes are required. Type I material is intended for use where the ultraviolet light absorbing properties specified in tables I or II, as applicable, are required. Type II material is intended for use where the ultraviolet light absorbing properties, specified for type I material, are not required. Type I and II sheet are not intended for use in aircraft glazing or other applications requiring consistently high optical quality. Type III sheet is intended for use in applications requiring good optical quality, cleanability or serviceability under adverse environmental conditions. Applications include diffusing lighting shields, window glazing, card holders, chart covers, edge lighted signs, surgical instrument handles and parts, safety shielding and transparent models. Type III sheet is not readily cemented using conventional cements for acrylic resins. The coating can be removed by sanding or buffing the areas to be cemented. Continuous cast sheet have better thermoformability than cell cast sheet, and the continuous cast process is less expensive.. However, It should be cautioned that, if the continuous cast sheet are to be used in forming applications, frequent adjusting (temperature, pressure, time of forming cycle, etc.) of the forming machinery may be required and this could offset any savings. Due to the continuous mixing, the uniformity of blend for the continuous cast sheet may be less consistent than that of the cell cast sheet which is cast from a premixed batch. Also due to the ripple effects (waves) the continuous cast sheet may be marginal in use for applications such as optical windows.

6.2 Ordering data. Purchasers should select the preferred options permitted herein and include the following information in procurement documents:

(a) Title, number, and date of this specification.
(b) Type and grade of cast methacrylate sheets, rods, or tubes, as applicable. Type III sheet shall be coated both sides unless otherwise stated.
(c) Use of cell cast or continuous casting process, if required.
(d) Color and method of determination, including uniformity if required (see 3.6). Also, end color standard for rods and tubes, when required (see 3.6.1), including method of determination.
(e) Simulated weathering resistance if required (see 3.4).
(f) Specific gravity, if pigmented material is required (see tables I and II).
(g) Deflection temperature, if thickness is less than 0.060 (see table I).

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(h) Length, width and nominal thickness of sheets (see 3.7.1). Length and nominal diameter of rods (see 3.7.2)
(i) Length, nominal outside diameter, and nominal wall thickness of tubes (see 3.7.3).
(j) Turbidity standard for rods and tubes, when required (see 3.8.4.2). Also, method for determination.
(k) Periodic lot check tests, when required (see 4.2.3.3).
(l) Adjustment of spectral transmittance value for sheet, if required (see 4.3.1.1).
(m) Selection of the applicable levels of packaging and packing required (see 5.1 and 5.2).
(n) Quantities of rods and tubes required in the unit packages

6.3 Terminology. As used in this specification tubes and tubing are identical.

6.4 Cross index. Table XIV shows the classification of material covered by this specification and the corresponding classification of material.

TABLE XIV. Classification in this document and corresponding classification in L-P-391C

L-P-391D	Classification in L-P-391C
Type I	Type I
Type II	Type II
Type III	None
Grade A sheet	Grade A
Grade B sheet	Grade D
Grade C sheet	Grade C
None	Grade B sheet
Grade A rods and tubes	Grade A
Grade B rods and tubes	Grade A

6.5 Disposability of packaging and packing materials. Environmental pollution preventive measures are contained in the packaging and packing material specifications indicated in section 2. Refer to these specifications for recommended disposability methods.

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MILITARY CUSTODIANS:

Army - MR
Navy - SH
Air Force - 11

Preparing activity:

Army - MR

Civil Agency Coordinating Activities:

GSA-FSS

Review activities:

Army - EL, MI, ME
Navy - AS, SH
DSA - GS

User activities:

Army - GL, PA
Navy - OS, YD

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INCH-POUND

L-P-391D
AMENDMENT 1
6 June 1990

FEDERAL SPECIFICATION
PLASTIC SHEETS, RODS AND TUBING, RIGID CAST, METHACRYLATE (MULTIAPPLICATION)

This amendment forms a part of Federal Specification L-P-391D dated 19 November 1975 and is approved for use by the Department of the Army and is available for use by all Departments and Agencies of the Department of Defense.

PAGE B-2

3.8.2 Delete the first sentence and substitute the following:
"Masked sheets of thickness equal to or less than 2.000 inches shall be free of let-goes within their specified minimum nominal length and width.

NOTE: A let-go is commonly defined as an area of laminated glass where the initial adhesion between glass and interlayer is debonded.

Custodians:
Army - MR
Navy - SH
Air Force - 11

Review activities:
Army - CR, MI, ME
Navy - AS
DLA - GS

User activities:
Army - GL, PA
Navy - OS, YD

Preparing activity:
Army - MR

Civil Agency Coordinating Activities:

GSA - FSS (7EXEG)
ERDA
NASA MSF

Project 9330-1149

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NOTICE OF VALIDATION

L-P-391D
NOTICE 1
10 February 1987

TITLE: Plastic Sheets, Rods and Tubing, Rigid Cast, Methacrylate (Multiapplication)

L-P-391D, dated 19 Nov 75, has been reviewed and determined to be valid for use in acquisition.

Custodians:
Army - MR
Navy - SH
Air Force - 11

Military Coordinating Activity:
Army -MR

AMSC N/A

FSC 9330

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